DISSERTATION

FOR THE AWARD OF DEGREE

MASTER OF SCIENCE

SESSION 2022-2025

IMPACT OF URBAN POLLUTION ON PULMONARY FUNCTION IN YOUNG ADULTS USING FIXED SITE AIR QUALITY DATA

MSc. Medical Physiology

Submitted By

Sadhvi

Batch (2022- 2025)

DEPARTMENT OF PHYSIOLOGY

SANTOSH DEEMED TO BE UNIVERSITY

NO. 1, SANTOSH NAGAR, GHAZIABAD-201009,

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-Ms. Sadhvi

ABBREVIATIONS

1. PM	PARTICULATE MATTER
2. $PM_{2.5}$	PARTICULATE MATTER WITH DIAMETER LESS THAN2.5 MICROMETERS (MICRONS)
3. PM_{10}	PARTICULATE MATTER WITH DIAMETER LESS THAN 10 MICROMETERS (MICRONS)
4. NO_2	NITROGEN DIOXIDE
5. BMI	BODY MASS INDEX
6. PFT	PULMONARY FUNCTION TEST
7. FVC	FORCED VITAL CAPACITY
8. FEV_1	FORCED EXPIRATORY VOLUME IN 1 SECOND
9. CPCB	CENTRAL POLLUTION CONTROL BOARD (INDIA)
10. ATS	AMERICAN THORACIC SOCIETY
11. SD	STANDARD DEVIATION
12. AQI	AIR QUALITY INDEX
13. WHO	WORLD HEALTH ORGANISATION

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INTRODUCTION

INTRODUCTION

Pulmonary function tests (PFTs) serve as crucial diagnostic tools to assess lung mechanics and performance. These assessments are influenced by multiple parameters including anthropometry, geographic factors, genetic predispositions, socioeconomic background, and lifestyle habits. The development of lung capacity is closely associated with changes in body stature, particularly height and weight, both of which are in turn affected by nutritional status and physical activity levels. [1]

The health consequences of air pollution are complex, given the diverse sources of contaminants and their heterogeneous physiological effects. Inhalation of airborne pollutants can lead to significant respiratory damage. Particulate matter (PM), encompassing particles between 0.005 μm and 100 μm in size, is a major component of suspended particulate matter (SPM). Particles under 10 μm are classified as PM_{10}, while those less than 2.5 μm are categorized as $PM_{2.5}$.[2]

Chronic exposure to airborne pollutants has been shown to impair pulmonary parameters such as Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1), suggesting an insidious decline in respiratory health over time.[3] Rapid urban expansion globally has intensified pressure on natural and human resources, including land, housing, and transportation. Urban planning efforts are increasingly challenged by population demands, infrastructure deficits, and environmental stressors such as pollution and climate change.[4]

In arid regions like the Middle East, countries such as Kuwait frequently experience dust storms and house extensive petrochemical operations. Despite the elevated risk, public health authorities face challenges in evaluating pollution-related morbidity due to limited air quality surveillance and lack of longitudinal exposure data.[5]

PFTs have gained prominence not only for identifying respiratory disorders but also for monitoring disease progression and evaluating responses to environmental exposures. Numerous epidemiological investigations have identified a consistent association between prolonged pollution exposure and reductions in lung function. Occupational exposure to diesel exhaust, especially in confined spaces, has been recognized as a major pulmonary hazard.[6]

Even brief exposure to ambient particulate matter has been linked to acute respiratory consequences, including increased rates of morbidity and mortality, even when pollutant levels fall within permissible limits.[7]

Hazardous airborne chemicals are now regarded as major contributors to global premature mortality. A growing body of research suggests that sustained exposure to air pollution can induce pulmonary toxicity and elevate the risk of respiratory diseases such as asthma, chronic bronchitis, and chronic obstructive pulmonary disease (COPD). Contemporary studies are now exploring the effects of gaseous pollutants on lung function in individuals without pre-existing respiratory pathology.[8]

The breadth of evidence establishes air pollution as a pressing public health challenge, with documented multisystem health effects. The acceleration of urbanization has not only escalated pollutant levels but also diversified pollutant types in the ambient environment.[9]

In India, urban centers routinely encounter dangerously elevated $PM_{2.5}$ concentrations, largely attributable to vehicular traffic, biomass combustion, and industrial output. These exposures contribute significantly to the burden of respiratory and cardiovascular disease.[10]

One investigation employing a paired design revealed that pulmonary function indices—specifically FVC and FEV_1—declined significantly on high-pollution days relative to low-pollution periods, highlighting the reversible nature of short-term pollution effects on lung performance.[11]

Among the most harmful pollutants are fine particulate matter and aromatic hydrocarbons produced from incomplete combustion processes. A study conducted in Kolkata assessed respiratory symptoms in individuals exposed to heavy traffic emissions in three distinct zones categorized by vehicle density.[12]

Understanding the variables influencing serial PFT results is essential, particularly when assessments are repeated within short intervals. These evaluations are often required in close clinical monitoring and may be affected by various environmental and physiological confounders.[13]

Statistical power analysis is an essential component in designing studies that aim to detect meaningful differences or associations. It equips researchers with the ability to calculate required sample sizes and enhances the robustness of statistical conclusions.[14]

Spirometry, the most frequently utilized PFT, remains central to quantifying lung function. It is indispensable in both diagnosing respiratory illnesses and monitoring treatment responses or environmental impacts.[15]

Vehicular exhaust is a major source of urban air pollution. Developed nations have made substantial progress in reducing pollutant levels through regulatory standards and technological innovations in emissions control—an effort that is anticipated to continue improving air quality.[16]

Epidemiological studies conducted worldwide have consistently demonstrated that PM_{10} and other air pollutants contribute significantly to adverse health outcomes, particularly among susceptible populations such as the elderly, children, and individuals with pre-existing respiratory or cardiovascular conditions.[17]

In the Indian National Capital Region, particularly in Delhi, pollutant concentrations often surpass World Health Organization (WHO) safety thresholds. While effects on vulnerable populations like children and the elderly are well-studied, there is limited data concerning young adults—particularly women—despite their unique exposure patterns via commuting, household air pollution, and passive smoke.[18]

Gruchalla et al. (2008) studied 861 children with asthma over two years in multiple U.S. urban centers, employing repeated spirometry and symptom logs. Results indicated that children living in inner-city regions with concentrated vehicular and industrial emissions were particularly vulnerable to respiratory insults from pollution.[19]

NEED FOR THE STUDY

Pulmonary function assessments offer key insights into the status of lung and airway health. These evaluations are commonly used in clinical practice to detect subtle functional impairments and monitor respiratory conditions over time. [20]

Urban air pollution, particularly traffic-related emissions, has emerged as a major environmental health hazard. Numerous studies confirm that sustained exposure to vehicular pollutants is associated with increased incidence of respiratory morbidity and premature mortality. In urban settings, individuals are frequently subjected to episodic surges in pollutant concentrations—especially in high-traffic areas—heightening their susceptibility to short-term pulmonary disturbances. [21]

Although the health effects of ambient air pollution on children and older adults have been extensively documented, there is a paucity of research focusing on young adult women in metropolitan regions such as New Delhi. These demographic experiences considerable pollutant exposure via daily travel, indoor emissions, and environmental tobacco smoke, yet remains underrepresented in the scientific literature. [22]

Populations residing in urban slums face compounded risks due to the convergence of indoor and outdoor air pollution sources. In particular, women in lower socioeconomic brackets are exposed to biomass combustion within homes and to ambient traffic- and industry-related pollutants outdoors, making them an especially vulnerable group. [23]

Prior investigations conducted in polluted urban areas such as Mexico City have highlighted that individuals with chronic respiratory conditions—such as COPD—experience acute declines in pulmonary function when exposed to high levels of $PM_{2.5}$. These studies underscore the real-world consequences of sustained pollutant exposure on already-compromised respiratory systems. [24]

AIM AND OBJECTIVES

AIM: -

To evaluate the impact of urban air pollution on pulmonary function in young adults using fixed-site air quality data.

OBJECTIVES: -

To assess changes in pulmonary function parameters (FEV_1, FVC, and FEV_1/FVC ratio) in young adults following exposure to ambient urban pollutants.

RESEARCH QUESTION

What will be the impact of Urban Pollution on Pulmonary Function in young adults?

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Air pollution has been consistently linked to declining pulmonary function across multiple demographic and geographic contexts. Exposure to fine particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3) has been shown to impair key spirometric indices such as Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV_1), and the FEV_1/FVC ratio. Studies across diverse cohorts report significant inverse associations between pollutant concentrations and lung function markers. [7–9],[10]

In urban settings, vehicular emissions and industrial activities are major contributors to ambient air pollution. Repeated exposure to these pollutants is associated not only with chronic conditions such as asthma and COPD but also with subclinical respiratory compromise in healthy individuals.[11–13] Notably, studies conducted among petrol pump workers and traffic-dense regions have revealed measurable declines in FEV_1 and FVC, supporting the occupational vulnerability hypothesis.[6],[12]

The magnitude and duration of pollutant exposure also determine the nature of pulmonary impact. Acute exposure, even at permissible limits, can trigger transient reductions in lung function, particularly in sensitive populations such as children and elderly adults.[20],[26],[30] Long-term exposure, however, is associated with structural airway changes, impaired alveolar development, and reduced respiratory reserve.[36],[37] Several longitudinal analyses have documented progressive declines in lung function in association with cumulative air pollution exposure.[19],[31]

Young adults, often considered resilient, are not immune to pollution-induced respiratory effects. Studies conducted among healthy college students and young urban dwellers demonstrate significant reductions in FEV_1 and FEV_1/FVC ratios in association with elevated $PM_{2.5}$ and NO_2 levels.[34],[35] These changes may be early indicators of impaired airway function, with potential long-term consequences if exposure continues. The window of early adulthood, characterized by peak lung capacity, may also represent a critical period for long-term pulmonary programming.[53–56]

Environmental inequality plays a crucial role in exposure intensity and respiratory outcomes. Women residing in urban slums or low-income neighborhoods are particularly vulnerable due to dual exposure from indoor biomass combustion and outdoor emissions. Studies have confirmed that such settings are associated with significantly reduced pulmonary function in women, even in the absence of overt disease.[23],[40],[39]

Geographic variations further influence exposure-response patterns. In Middle Eastern countries such as Kuwait, frequent dust storms combined with petrochemical emissions exacerbate respiratory risk, as evidenced by elevated mortality and morbidity.[5] In India, ambient pollutant concentrations frequently exceed WHO safety guidelines, especially in urban centers like Delhi. Repeated spirometry-based evaluations in such environments have demonstrated consistent declines in FVC and FEV_1, particularly during high-pollution periods.[24],[25],[38]

Several child-based studies provide mechanistic insights into pollution-induced respiratory effects. Children exposed to high ambient levels of PM and gaseous pollutants show lower PEFR, FEF, and FVC values than those in cleaner environments.[2],[17],[20] Furthermore, sex-based differences in sensitivity have also been observed, with boys showing greater vulnerability to pollutant-associated lung function decline.[26]

Global historical data also corroborate the link between pollution and respiratory decline. Seminal events like the London Smog (1952) triggered investigations into the pulmonary consequences of poor air quality.[41] Landmark epidemiological studies such as the Harvard Six Cities Study and the work of Pope et al. in the early 2000s established a dose-response relationship between PM exposure and mortality.[42–43] Indian researchers have since contributed significantly to this literature, focusing on urban pollution and its respiratory sequelae among both symptomatic and asymptomatic individuals.[44]

The emergence of fixed-site air quality monitoring stations has enhanced exposure assessment precision. These stations provide standardized pollutant data that strengthen epidemiological correlations between pollutant levels and health outcomes. Their application has improved understanding of real-time pollutant exposure and its impact on pulmonary physiology. [45],[46]

Collectively, the literature indicates a robust and consistent association between ambient air pollution and reduced pulmonary function across populations, including healthy young adults. The evidence underscores the need for early detection, continuous monitoring, and targeted public health interventions to mitigate long-term respiratory damage.

AIR POLLUTION AND RESPIRATORY HEALTH

Short-term spikes in air pollution can rapidly trigger respiratory symptoms such as breathlessness, wheezing, and chest tightness, particularly in individuals with pre-existing respiratory illnesses like asthma or chronic obstructive pulmonary disease (COPD) (48). However, it is prolonged and repeated exposure that poses the greater long-term threat, contributing to persistent bronchitis, impaired pulmonary development, and increased mortality due to chronic respiratory conditions (49). According to the American Thoracic Society, no level of fine particulate matter can be considered completely safe; even minimal exposure is capable of inducing detrimental pulmonary effects (50).

PULMONARY FUNCTION TESTING

Pulmonary function testing (PFT) comprises a range of non-invasive assessments designed to measure lung volumes, airflow dynamics, and gas exchange capacity. These tests serve as a vital tool in diagnosing obstructive and restrictive lung diseases, as well as in monitoring disease progression and treatment efficacy (51).

Among the various modalities, spirometry remains the most standardized and widely used technique. It evaluates the following critical parameters:

- **Forced Vital Capacity (FVC)**: The maximum volume of air exhaled forcefully after full inhalation
- **Forced Expiratory Volume in 1 Second (FEV_1)**: The amount of air expelled during the first second of forced exhalation
- **FEV_1/FVC Ratio**: A diagnostic index for distinguishing between obstructive and restrictive airway pathologies

- **Peak Expiratory Flow (PEF)**: The fastest speed at which air can be exhaled during a forceful breath (51)

In environmental health research, spirometry is particularly useful due to its sensitivity to subtle changes in lung function. It is frequently employed in studies investigating the health effects of air pollutants. For instance, children living in polluted environments have demonstrated slower growth in FEV_1 and FVC compared to peers in cleaner areas (52). Likewise, young adults exposed to vehicular emissions or high concentrations of $PM_{2.5}$ and NO_2 show reductions in FEV_1/FVC ratios and signs of early airway obstruction (52).

VULNERABILITY OF YOUNG ADULTS

Despite being in their physiological prime, young adults (typically aged 18–25) are not immune to the adverse effects of air pollution. Their lifestyle often involves high exposure to ambient pollutants due to outdoor commuting, recreational activities, and frequent travel for education or work (53). This extended exposure window, especially in urban areas, increases their vulnerability to pollutant-induced respiratory stress.

Although chronic respiratory diseases are relatively rare in this demographic, pollution can still induce subclinical pulmonary changes. These may include airway inflammation, oxidative stress, and reduced lung reserve—all of which may remain asymptomatic yet contribute to future disease risk (54).

Recent studies from high-pollution urban zones, including Delhi and Kolkata, confirm that healthy young individuals—particularly college students—experience measurable declines in FEV_1 and FEV_1/FVC ratios, even in the absence of smoking or respiratory illness (55). Furthermore, long-term exposure during this critical developmental window can interfere with peak lung growth and increase lifetime susceptibility to asthma, COPD, and other chronic conditions (56).

FIXED-SITE AIR QUALITY MONITORING

Fixed-site air quality monitoring involves continuous, standardized measurement of airborne pollutants from specific geographic locations using calibrated stations. These stations, operated in India by the Central Pollution Control Board (CPCB), serve as reliable sources of pollutant data, providing region-specific exposure profiles for health research.

Key pollutants routinely monitored include particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3). Such pollutants are measured using reference-grade instrumentation that ensures consistency, accuracy, and inter-site comparability (56).

The major strength of this approach lies in its ability to offer population-representative exposure data, especially for urban settings. These measurements are crucial for linking pollutant levels to health outcomes in epidemiological and clinical research (57).

MATERIALS AND METHODS

MATERIALS AND METHODS

STUDY DESIGN

This was a longitudinal study conducted over a period of three months to evaluate the effect of urban pollution on pulmonary function.

STUDY LOCATION

The research was carried out at the Department of Physiology, Santosh Medical College and Hospital, Ghaziabad.

SAMPLE SIZE AND POPULATION

A total of 75 healthy young adults, aged 18–25 years, were enrolled. The final sample size was determined using statistical power analysis, targeting at least 64 participants for adequate effect detection.

INCLUSION CRITERIA

- Individuals aged between 18 and 25 years
- Continuous residence in the urban study region for ≥12 months
- Non-smokers
- Willingness to undergo repeated pulmonary function assessments

EXCLUSION CRITERIA

- History of smoking or recent respiratory infection (within 2 months)
- Known diagnosis of chronic respiratory conditions (e.g., asthma, bronchitis)
- Occupational exposure to air pollutants
- Diagnosed cardiovascular or metabolic disorders affecting lung function

STUDY OF SCOPE:

- This study targets young adults aged 18–25 years, evaluating pulmonary function metrics before and after exposure to urban environments. Findings may inform strategies for health promotion and pollution control policies in urban settings.

STUDY PROCEDURE

- Participants were briefed about the study and written informed consent was obtained. A structured questionnaire was administered to collect demographic data, health history, and exposure-related variables.
- Pulmonary Function Tests (PFTs) were conducted using spirometry (Clarity – SPIROTECH CMSP-01, SN: ST-EOSE-0310), following American Thoracic Society (ATS) guidelines.

PFT PARAMETERS RECORDED

- FVC – Forced Vital Capacity
- FEV_1 – Forced Expiratory Volume in 1 second
- FEV_1/FVC ratio

TIMELINE OF ASSESSMENTS

1. **Baseline:** Initial spirometry conducted before exposure assessment
2. **24 Hours Post Exposure**: Air quality data from CPCB fixed-site monitoring stations logged
3. **12 Weeks:** Follow-up spirometry repeated to evaluate longitudinal change in pulmonary function
   - Symptom Questionnaire administered again at follow-up

AIR QUALITY DATA COLLECTION

Pollutant data ($PM_{2.5}$, PM_{10}, NO_2) were obtained from CPCB monitoring stations located in:-

- East Ghaziabad (Indirapuram, Mohan Nagar, Raj Nagar Extension, Vasundhara)
- North Ghaziabad (Loni Dehat, Shahdara, Vijay Nagar)
- West Ghaziabad (Sector 61 & 62, Siddharth Vihar)
- South Ghaziabad (Suraj Nagar, Ghaziabad)

- Hourly and daily pollutant concentrations were downloaded from airquality.cpcb.gov.in to estimate real-time exposure.

PHYSICAL MEASUREMENTS

Height and weight were recorded using standard instruments to calculate Body Mass Index (BMI). These variables were included as potential confounders in multivariate analysis.

STATISTICAL ANALYSIS

- Primary analysis involved paired t-tests (or non-parametric equivalents) to compare pulmonary function before and after exposure.

- Friedman test was applied for repeated non-normally distributed data across three time points.

- Mann–Whitney U test with Bonferroni correction was used for pairwise comparisons.

- Multivariate regression models were built to assess the association between pollutant levels and pulmonary function decline, adjusting for BMI and other covariates. (17)

DATA COLLECTION TOOLS AND TECHNIQUES

1. Pulmonary Function Tests (PFTs):

(a) Spirometry will be conducted before and after the exposure period using a standardized spirometer, measuring FVC, FEV_1, and FEV_1/FVC ratio according to American Thoracic Society (ATS) guidelines[15].

2. Fixed-Site Air Quality Data:

(a) For urban pollution – Most polluted areas like Sector 62, Indirapuram, Knowledge Park 5, etc. through cpcb.nic.in

(b) Hourly and daily pollutant levels from these stations will serve as proxies for Participants exposure levels[16].

3. **Questionnaire:**

(a) A structured questionnaire will gather demographic information, lifestyle habits, and respiratory symptoms.

4. **Physical Measurements**:

(a) Height, weight, and BMI will be recorded as potential confounding variables.

DATA ANALYSIS

1. **Primary Analysis**:

(a) Paired t-tests will be use to compared pre- and post-exposure pulmonary function values (FEV_1, FVC).

2. **Multivariate Analysis**:

(a) Multiple regression models will examine the impact of pollutant levels ($PM_{2.5}$, PM_{10}, NO_2) on pulmonary function changes, adjusting for BMI and other covariates[17].

STUDY DESIGN FLOW CHART

Longitudinal Study
Subjects taken after inclusion and exclusion criteria
Informed Consent for baseline PFT and questionnaire
PFT measure after 24 hrs
PFT and questionnaire measure after 12 weeks
Data Collection (PFT measurement)
Data Analysis
Statistics and Interpretation of Data
Result/Outcome
Discussion/Summary

OUTCOME OF STUDY

The study will provide critical data on the short-term effects of urban pollution on young adult's pulmonary function, with potential implications for public health policies aimed at mitigating pollution exposure risks.

Sample size Calculation: -

$$n = \frac{2(\sigma^2)(Z_{\alpha/2} + Z_{\beta})^2}{\Delta^2}$$

The estimated sample size is a approximately 64 participants.

Where:

- n = sample size per group
- σ = standard deviation for the outcome measure
- $Z_{\alpha/2}$ = Z value corresponding to alpha level (for α = 0.05, $Z_{\alpha/2} = 1.96$)
- Z_{β} = Z value corresponding to desired power (for 80% power, $Z_{\beta} = 0.84$)
- Δ = expected difference between the groups (effect size)

For Pulmonary Function: -

- Effect size (Cohen's d) = 0.5
- SD = 0.3 L
- Alpha = 0.05, Power = 80%
- $Z_{\alpha/2} = 1.96$, $Z_{\beta} = 0.84$
- $\Delta = 0.5 \times 0.3 = 0.15$ (medium effect)

Using the formula:

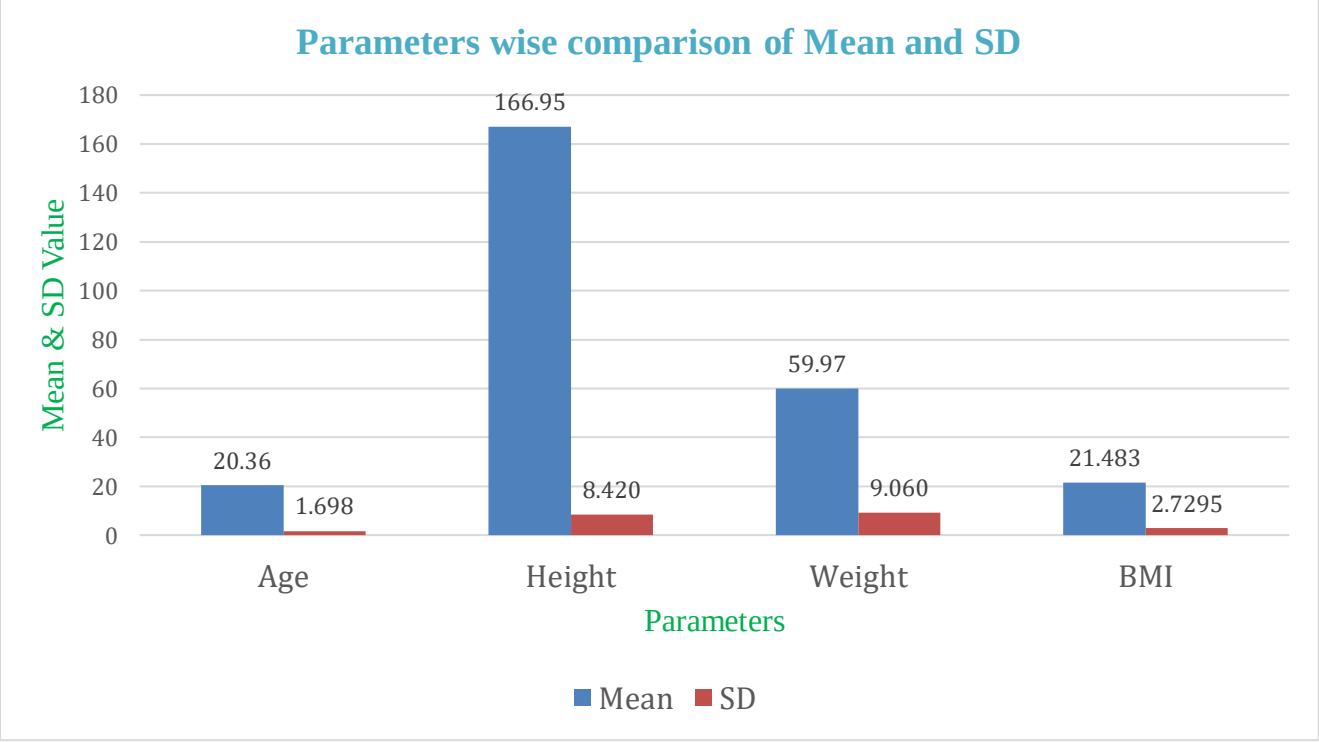
$$n = \frac{2(0.3^2)(1.96 + 0.84)^2}{0.15^2} \approx 64 \text{ participants per group}$$

- For physical Measurements: Height, weight, and BMI was recorded as potential confounding variables.

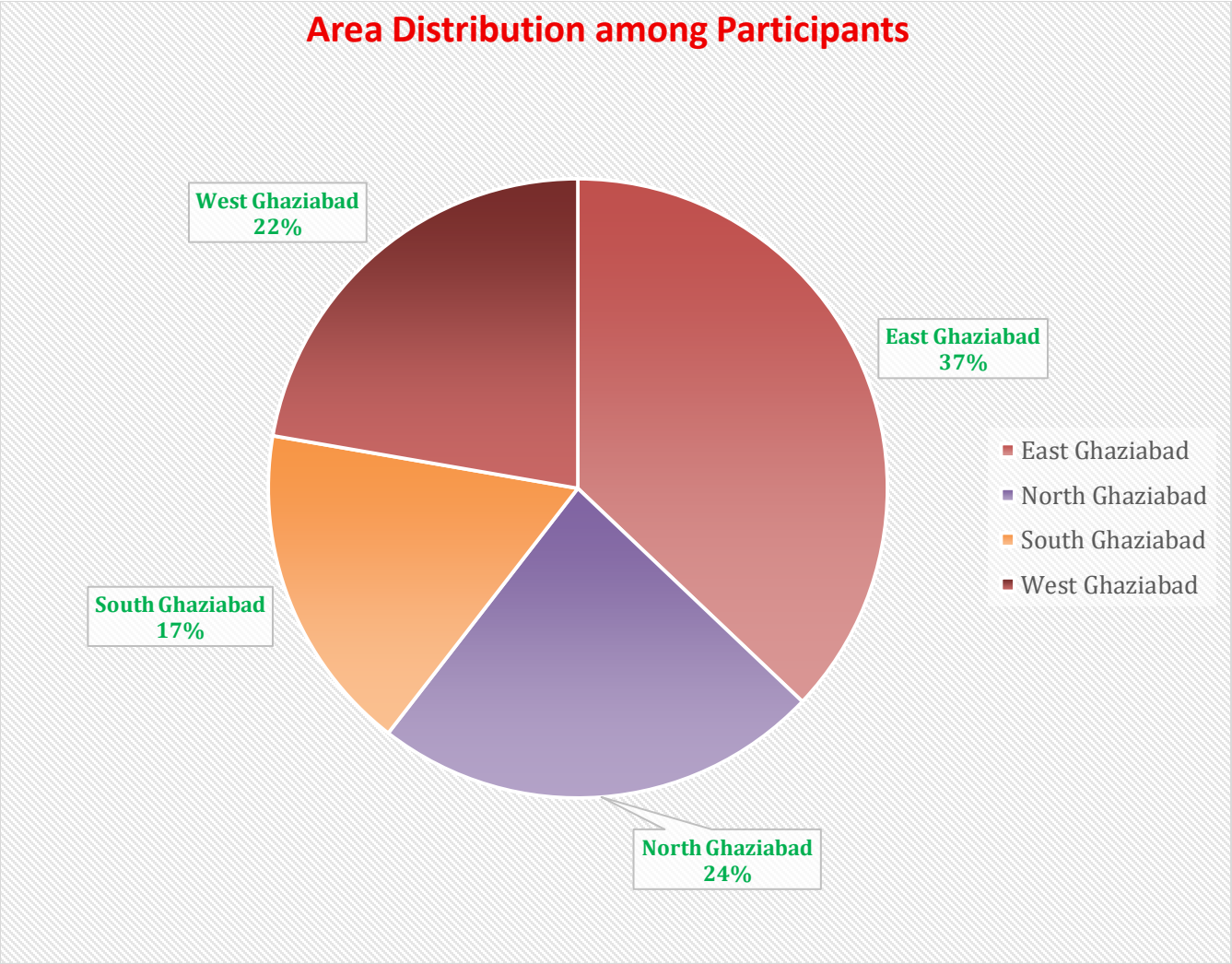
RESULTS

RESULT

Parameters	Mean	SD
Age	20.36	1.698
Height	166.95	8.420
Weight	59.97	9.060
BMI	21.483	2.7295



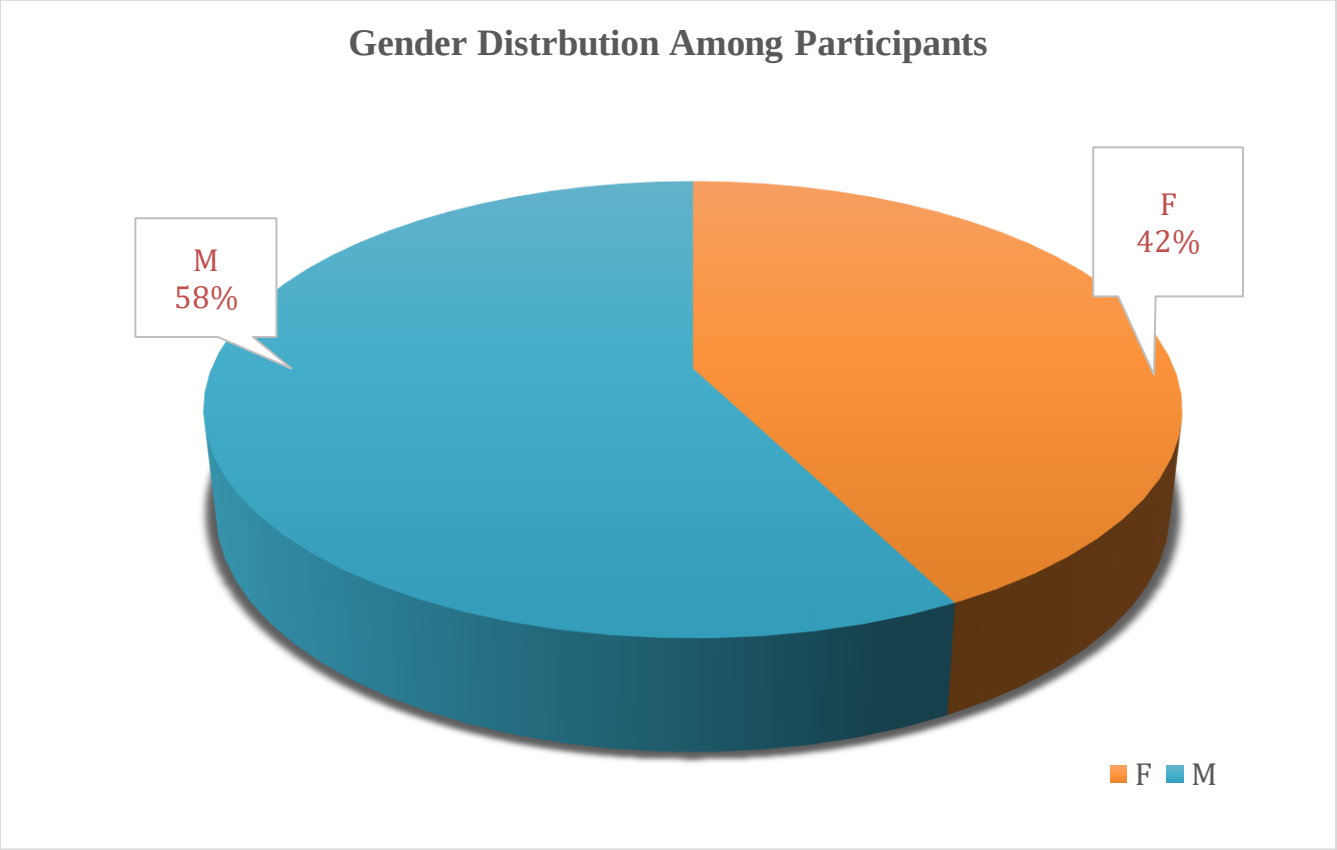
The study participants had a mean age of 20.36 ± 1.70 years. Participants had an average height of 166.95 ± 8.42 cm and an average weight of 59.97 ± 9.06 kg. The mean Body Mass Index (BMI) was 21.48 ± 2.73 kg/m².



The area-wise distribution of participants, illustrated in the pie chart, shows that the highest proportion of samples belonged to **East Ghaziabad**, accounting for **37%** of the total sample. This was followed by **North Ghaziabad**, which contributed **24%** of the participants. **West Ghaziabad** constituted **22%**, while the lowest representation was from **South Ghaziabad**, with **17%** of the participants.

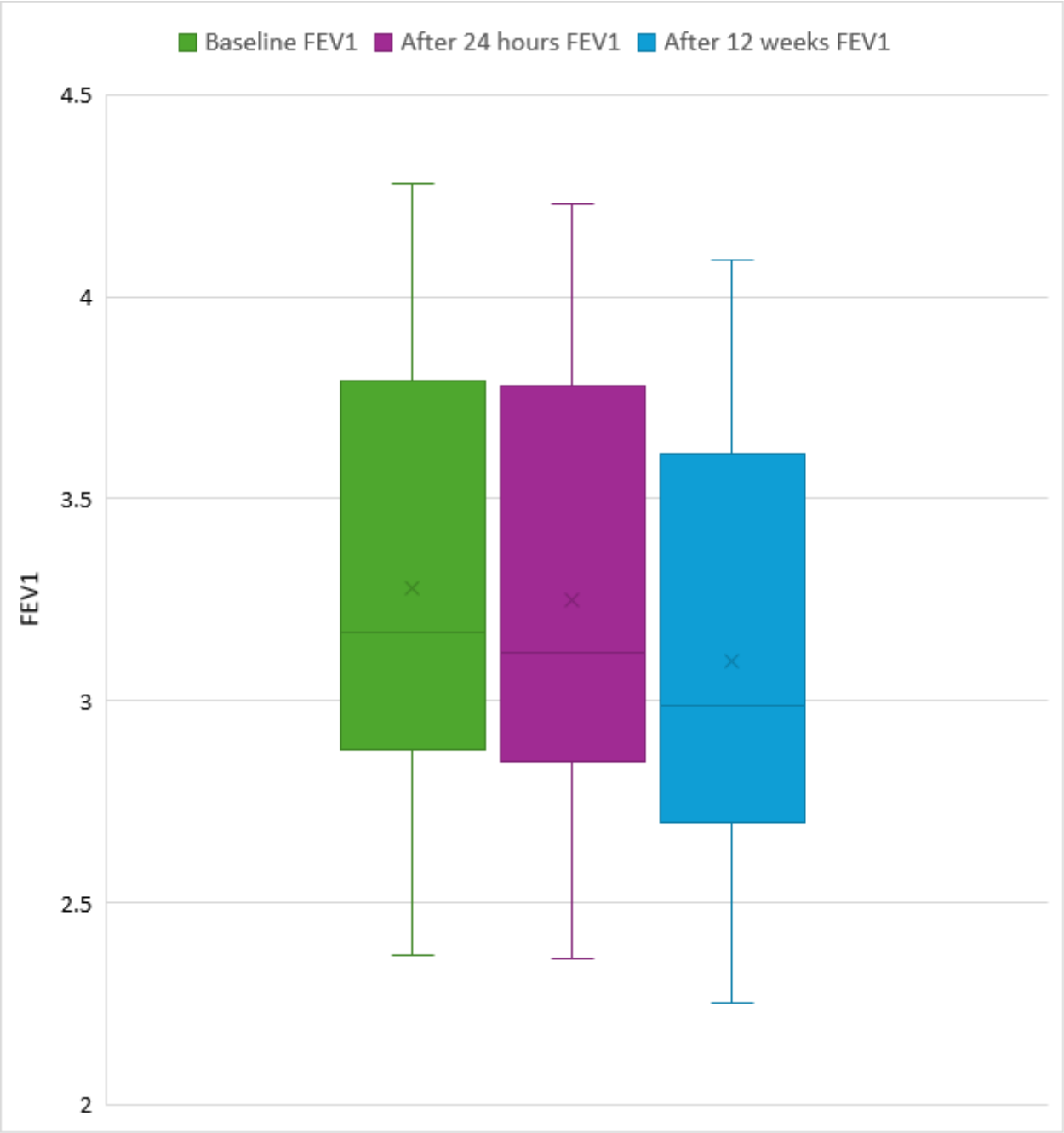
Gender Wise Distribution of Participants

Sex	Number	%
Male	43	57.33
Female	32	46.66

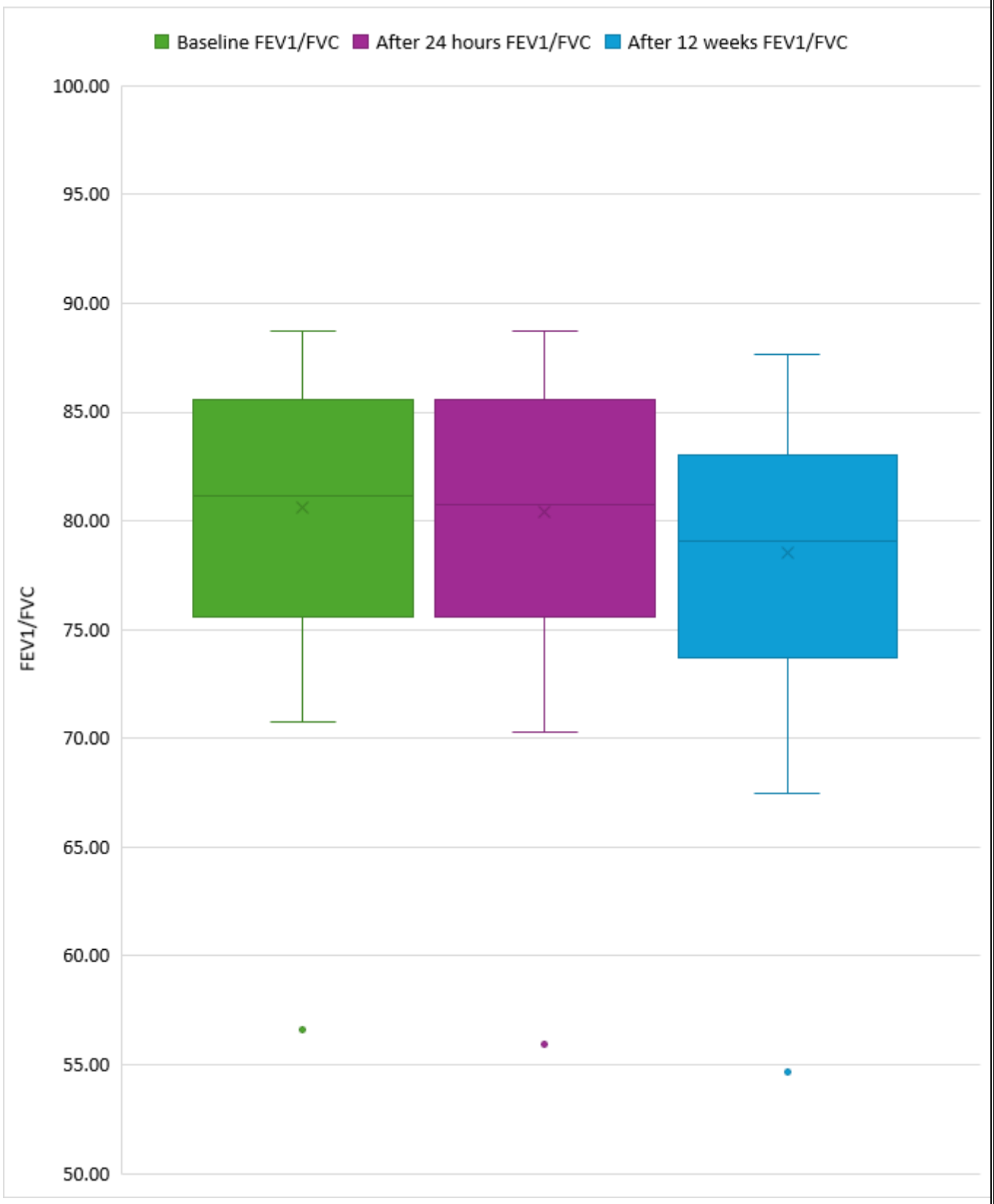


- The gender distribution among the study participants, as illustrated in the pie chart, shows a higher representation of males, who comprised 58% of the sample. In comparison, females accounted for 42% of the participants.

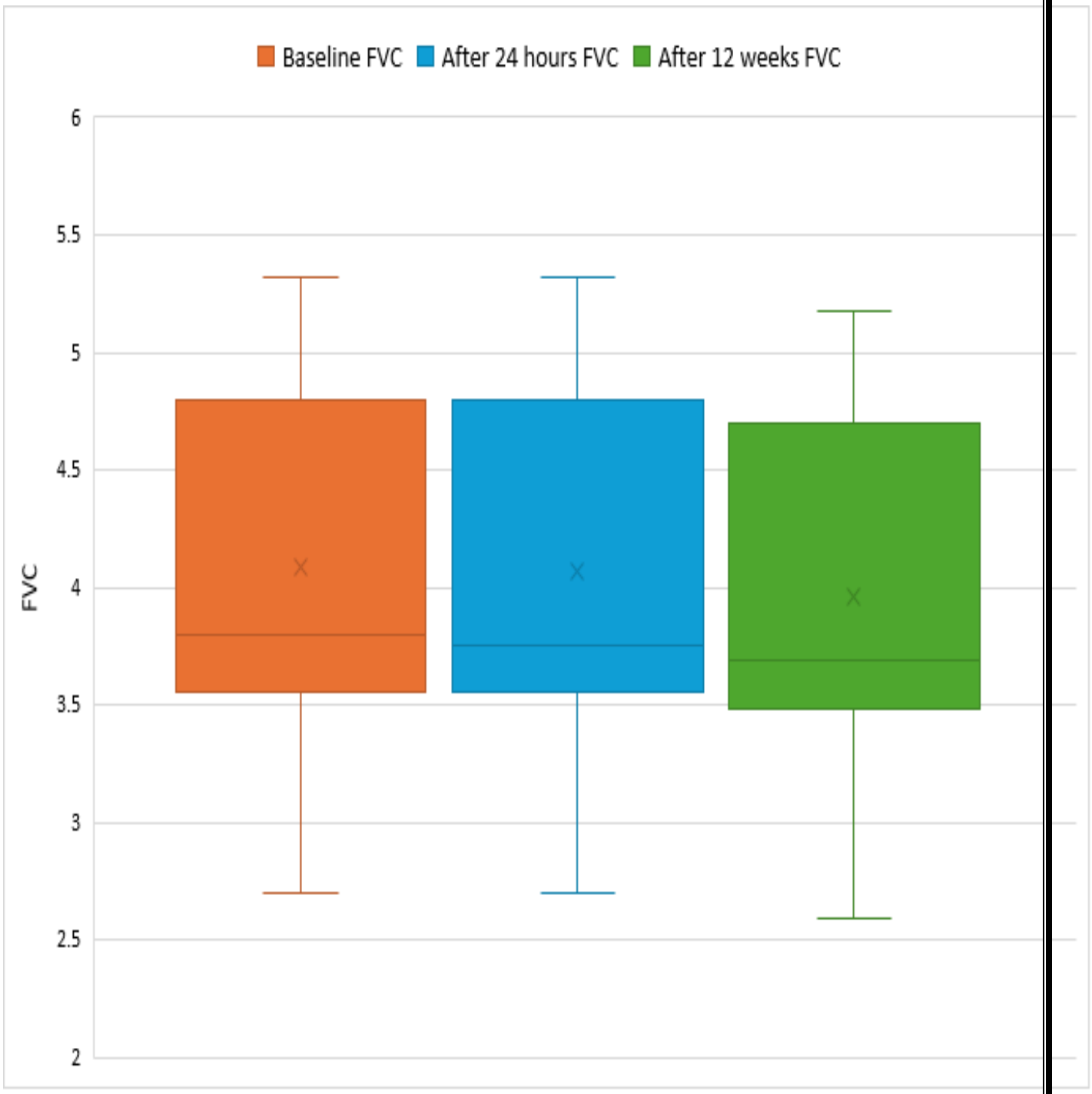
FEV1 Distributions: Baseline, 24 Hours, and 12 Weeks


Baseline FEV1
After 24 hours FEV1
After 12 weeks FEV1
4.5
4
3.5
3
2.5
2
FEV1

FEV1/FVC Distributions: Baseline, 24 Hours, and 12 Weeks



FVC Distributions: Baseline, 24 Hours, and 12 Weeks



Friedman test was used

Parameter	Timeline	Mean	SD	p-value
FVC	Baseline	4.08	0.69	0.000
	After 24 hours	4.06	0.69	
	After 12 weeks	3.96	0.70	
FEV1	Baseline	3.27	0.51	0.000
	After 24 hours	3.25	0.51	
	After 12 weeks	3.09	0.50	
FEV1/FVC	Baseline	80.63	5.76	0.000
	After 24 hours	80.39	5.79	
	After 12 weeks	78.50	5.74	

Because the data violated the assumption of normality, the Friedman test, a non-parametric substitute for repeated measures ANOVA, was used to evaluate changes in pulmonary function parameters (FVC, FEV1, and FEV1/FVC) across three time points: baseline, after 24 hours, and after 12 weeks.

The mean FVC demonstrated a gradual decline over time, from 4.08 ± 0.69 L at baseline to 4.06 ± 0.69 L at 24 hours, and further to 3.96 ± 0.70 L at 12 weeks. While the change between baseline and 24 hours was minimal and likely not clinically significant, the cumulative decline over 12 weeks was more pronounced.

The Friedman test indicated a statistically significant difference, with a p-value of less than (0.001). in FVC values across the three time points, indicating a significant longitudinal change in forced vital capacity.

A similar pattern was observed for FEV_1, with mean values decreasing from 3.27 ± 0.51 L at baseline to 3.25 ± 0.51 L at 24 hours, and further to 3.09 ± 0.50 L at 12 weeks. The marginal reduction at 24 hours was followed by a notable decline by 12 weeks, suggesting a progressive deterioration in expiratory function. This temporal trend was statistically significant ($p = 0.000$), as indicated by the Friedman test.

The FEV_1/FVC ratio showed a downward trend from 80.63 ± 5.76 at baseline to 80.39 ± 5.79 at 24 hours, with a more substantial drop to $78.50 \pm 5.74\%$ at 12 weeks. Although the initial 24-hour change was negligible, the decline by 12 weeks may be indicative of increasing airflow limitation or early obstructive pulmonary changes. The Friedman test confirmed a statistically significant difference

($p = 0.000$) in the FEV_1/FVC ratio over time.

Mann Whitney U test was used			
Parameter	**Timeline**	**Mean Difference**	**p-value**
FVC	Baseline - After 24 hours	0.025*	0.000
	Baseline - After 12 weeks	0.181*	0.000
	After 24 hours -After 12 weeks	0.155*	0.000
FEV1	Baseline - After 24 hours	0.019*	0.000
	Baseline - After 24 hours	0.119*	0.000
	After 24 hours -After 12 weeks	0.100*	0.000
FEV1/FVC	Baseline - After 24 hours	0.240*	0.000
	Baseline - After 24 hours	2.128*	0.000
	After 24 hours -After 12 weeks	1.887*	0.000

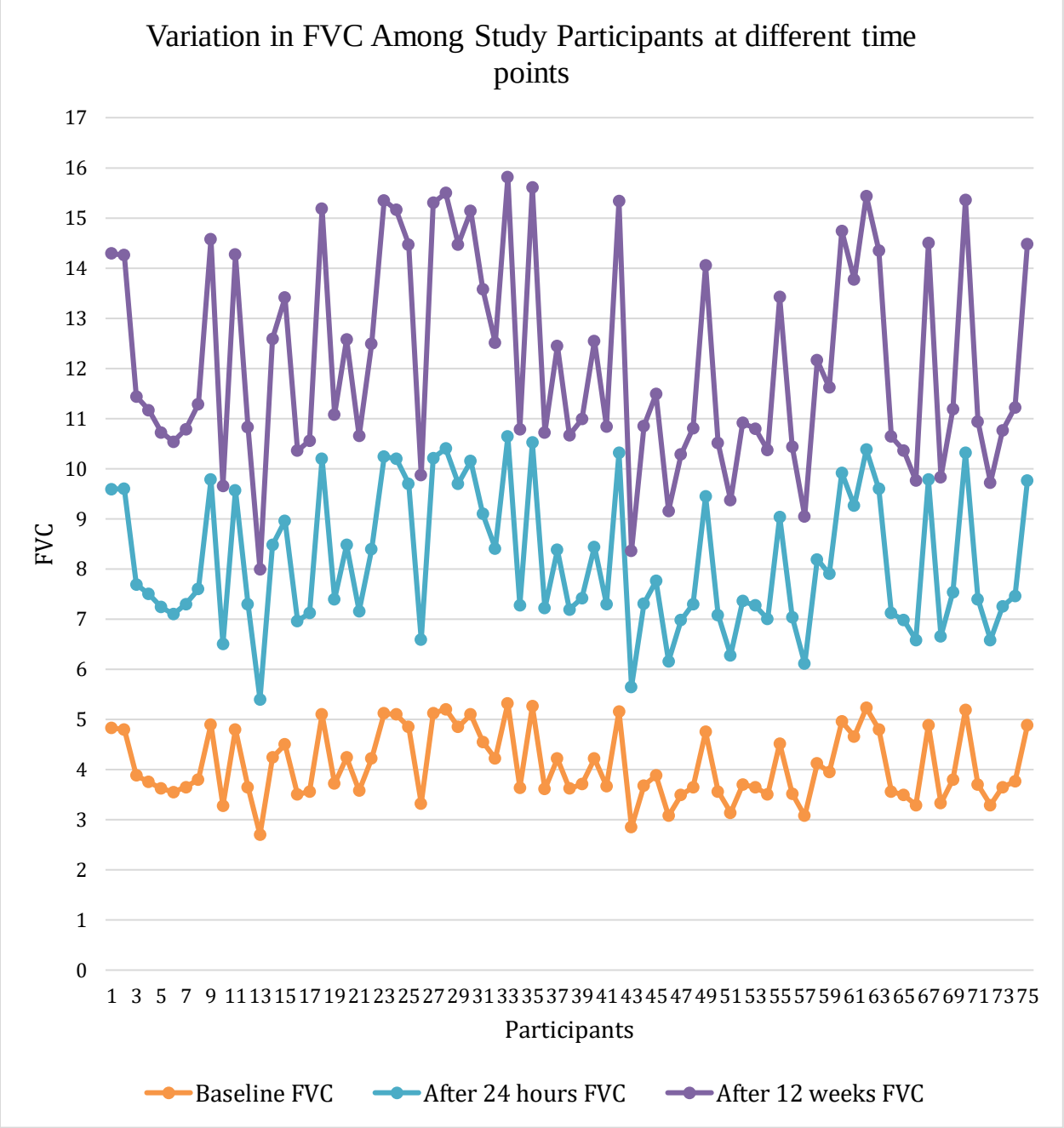
Based on estimated marginal means

***** The difference in means is statistically significant at the 0.05 level.

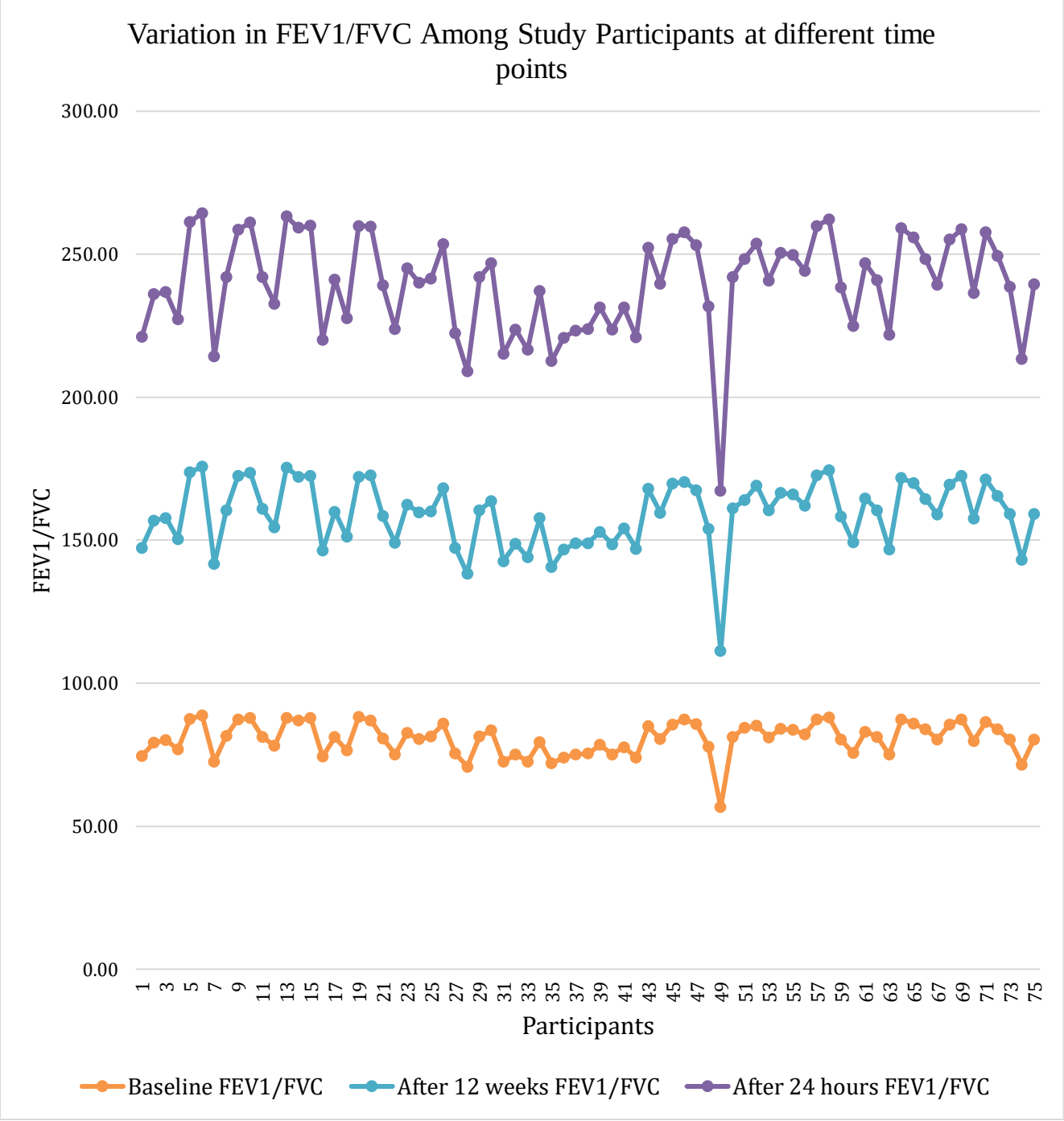
b. Multiple comparisons have been adjusted using the Bonferroni correction. **

To explore the pairwise differences across time points following the significant Friedman test results, the Mann–Whitney U test was used with Bonferroni correction for multiple comparisons. The analysis revealed that changes in FVC between baseline and 24 hours were statistically significant

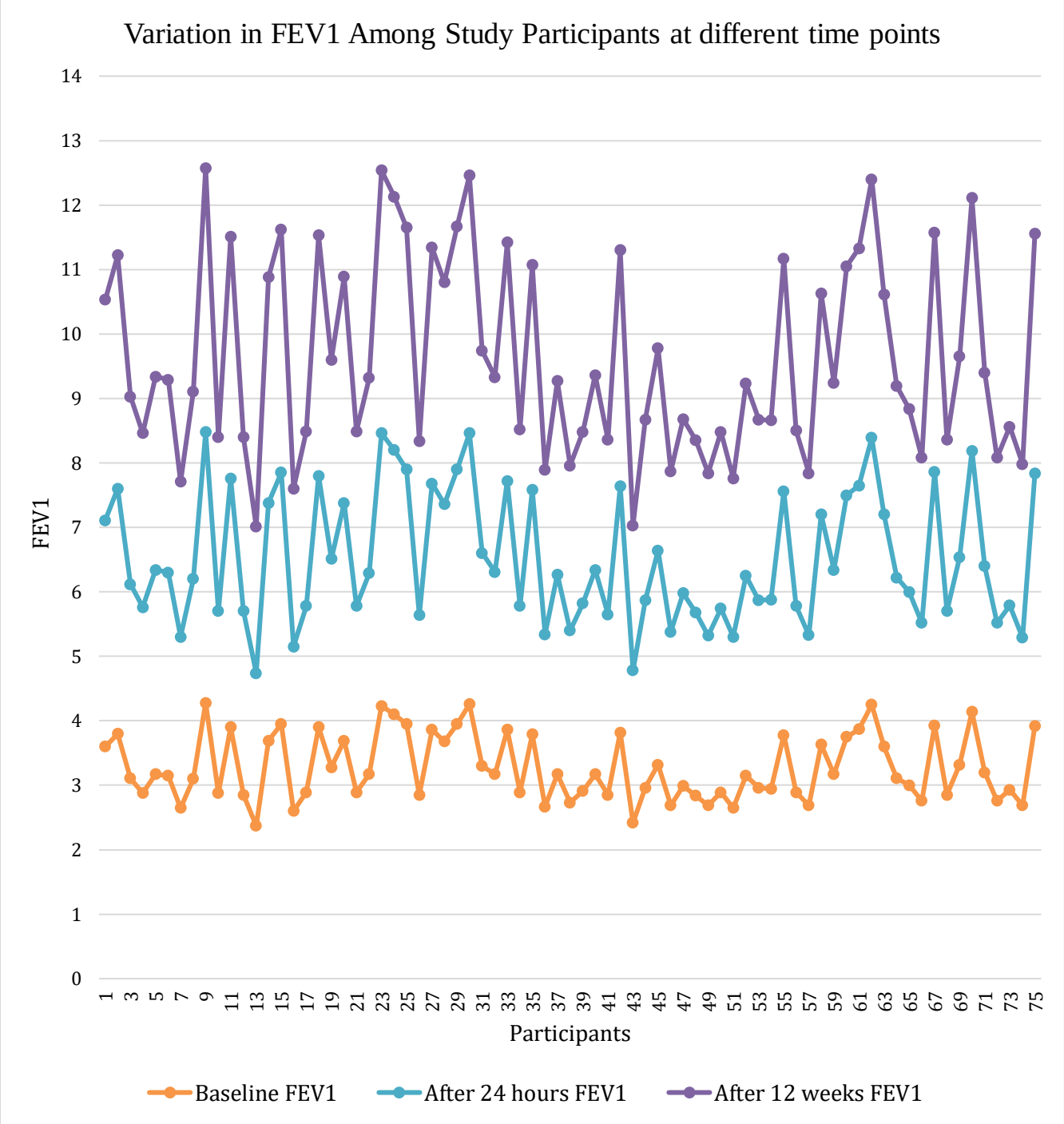
(mean difference = 0.025 L, $p = 0.000$), although the magnitude of change was minimal and likely not clinically meaningful. A more pronounced relevant decline was observed between baseline and 12 weeks (mean difference = 0.181 L, $p = 0.000$), as well as between 24 hours and 12 weeks (mean difference = 0.155 L, $p = 0.000$), indicating a progressive reduction in forced vital capacity over time. Similarly, FEV_1 showed a statistically significant but small change from baseline to 24 hours (mean difference = 0.019 L, $p < 0.001$), followed by a more notable decline from baseline to 12 weeks (mean difference = 0.119 L, $p < 0.001$) and from 24 hours to 12 weeks (mean difference = 0.100 L, $p = 0.000$). The FEV_1/FVC ratio also declined significantly across all time intervals, with a negligible change between baseline and 24 hours (mean difference = 0.240%, $p = 0.000$) but a substantial and clinically significant reduction from baseline to 12 weeks (mean difference = 2.128%, $p=0.000$) and from 24 hours to 12 weeks (mean difference = 1.887%, $p = 0.000$).



The line graph illustrates individual-level variation in FVC among the study participants (n = 75) at three time points: baseline, after 24 hours, and after 12 weeks.


Variation in FEV1/FVC Among Study Participants at different time points
300.00
250.00
200.00
150.00
100.00
50.00
0.00
FEV1/FVC
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75
Participants
Baseline FEV1/FVC
After 12 weeks FEV1/FVC
After 24 hours FEV1/FVC

The line graph illustrates individual-level variation in FEV1/FVC among the study participants (n = 75) at three time points: baseline, after 24 hours, and after 12 weeks.



The line graph illustrates individual-level variation in FEV1 among the study participants (n = 75) at three time points: baseline, after 24 hours, and after 12 weeks.

PICTURES

1. KRUPS analog weighing machine to measure weight, which can measure up to 120 kg.

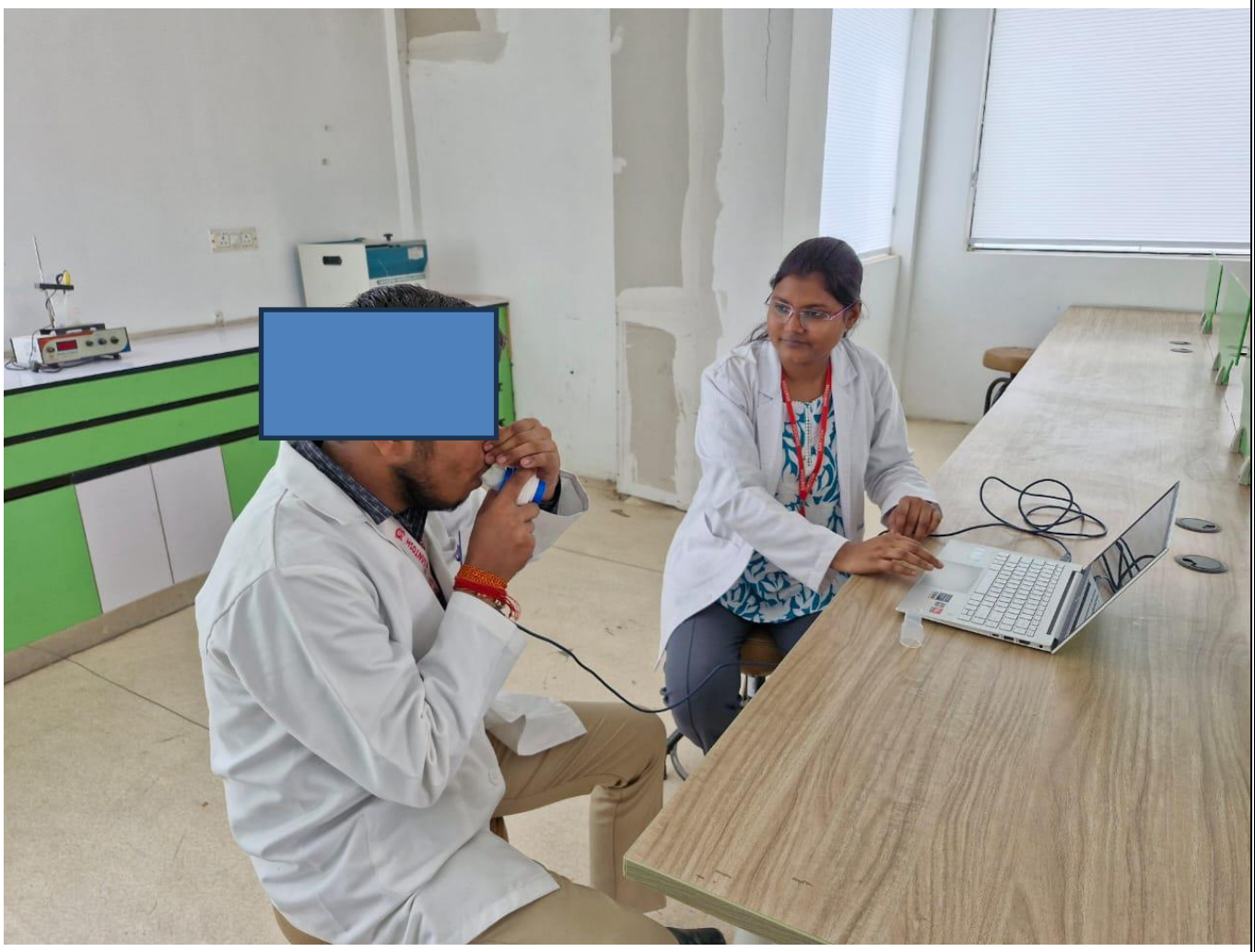
PICTURE NO.1: WEIGHING MACHIN

2. Stadiometer Measuring Tape To Measure Height

PICTURE NO.2: STADIOMETER

3. Spirometer (Clarity Spiro Tech CMSP-01) to measure pulmonary function parameters

PICTURE NO.3: SPIROMETER



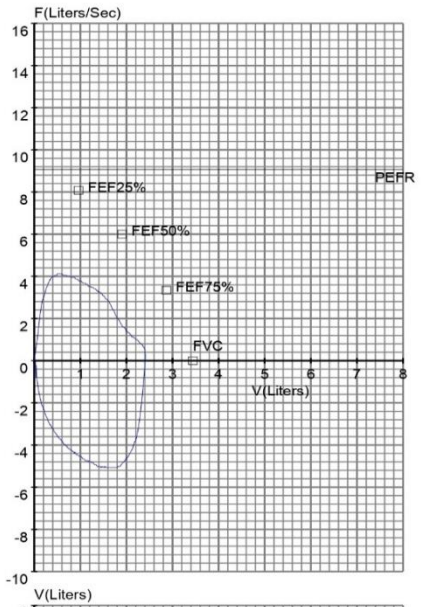
PICTURE NO.4: PICTURE DEPICTING PERFORMING SPIROMETRY

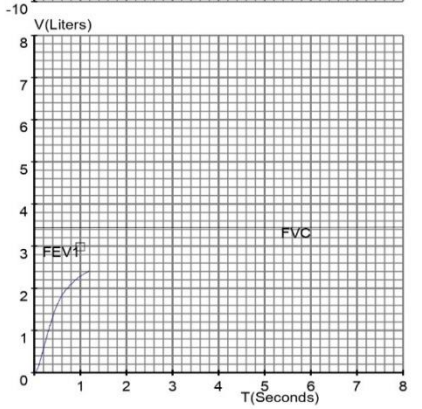
Clarity

112 - MUSHAHID
23 Years / Male / Ht 165 Cms /90 Kgs / Non-Smoker

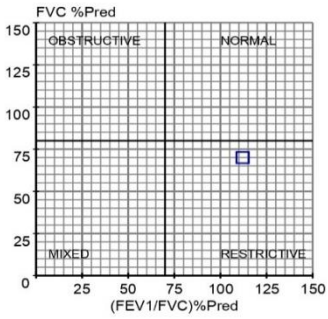
FVC TEST
Date: 10-07-2025 (T3)

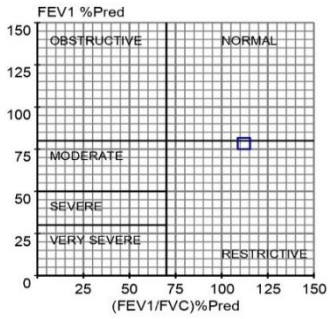
Pred Eqn : CLARITY Eth.Corr : 100 Temp : 0°C
Ref By : NONE





Parameter		Pred	Pre	Pre%	Post	Post%	Imp%
FVC	[L]	3.44	2.40	70	--	--	--
FEV1	[L]	2.99	2.34	78	--	--	--
FEV.5	[L]	--	1.77	--	--	--	--
FEV3	[L]	3.33	--	--	--	--	--
FEV6	[L]	--	--	--	--	--	--
PEFR	[L/s]	9.09	4.14	46	--	--	--
FEF25-75	[L/s]	4.61	3.41	74	--	--	--
FEF75-85	[L/s]	--	1.68	--	--	--	--
FEF.2-1.2	[L/s]	7.79	3.73	48	--	--	--
FEF25%	[L/s]	8.05	4.56	57	--	--	--
FEF50%	[L/s]	6.00	3.80	63	--	--	--
FEF75%	[L/s]	3.35	1.99	59	--	--	--
FEV.5/FVC	[%]	--	73.85	--	--	--	--
FEV1/FVC	[%]	86.88	97.41	112	--	--	--
FEV3/FVC	[%]	97.00	--	--	--	--	--
FEV6/FVC	[%]	--	--	--	--	--	--
FEV1/FEV6	[%]	--	--	--	--	--	--
FET	[S]	--	1.09	--	--	--	--
ExplTime	[S]	--	0.18	--	--	--	--
LungAge	[Y]	23.00	28.00	122	--	--	--
FIVC	[L]	--	2.39	--	--	--	--
PIFR	[L/s]	--	5.09	--	--	--	--
FIF25%	[L/s]	--	4.56	--	--	--	--
FIF50%	[L/s]	--	3.96	--	--	--	--
FIF75%	[L/s]	--	2.66	--	--	--	--
FIV.5	[L]	--	2.00	--	--	--	--
FIV1	[L]	--	--	--	--	--	--
FIV3	[L]	--	--	--	--	--	--
FIV.5/FIVC	[%]	--	83.66	--	--	--	--
FIV1/FIVC	[%]	--	--	--	--	--	--
FIV3/FIVC	[%]	--	--	--	--	--	--





- Pre Medication Report :
Early Small Airway Obstruction.Spirometery shows M
ild Restriction as FVC% < 80 And FEV1/FVC% > 70

- Pre COPD Severity Report:
COPD Severity is Restrictive

- Doctor's Comments :

NONE

PICTURE NO.5: GRAPH AND PICTURE OF SPIROMETRY RESULTS

DISCUSSION

DISCUSSION

The findings of this study provide compelling evidence that even short- to medium-term exposure to urban air pollution leads to measurable deterioration in pulmonary function among young adults. Despite the absence of known respiratory pathology and the non-smoking status of all participants, a consistent downward trend was observed across key spirometric parameters—FVC, FEV_1, and FEV_1/FVC ratio—over the 12-week study duration.

Although the initial changes recorded within 24 hours of exposure were relatively small in magnitude, they reached statistical significance, indicating that even acute pollutant exposure can trigger subtle respiratory stress. Over time, these effects became more pronounced, suggesting a cumulative impact that compromises both lung volume and airway efficiency.

The use of fixed-site air quality monitoring notably strengthened the environmental exposure assessment, ensuring the reliability and relevance of the pollution data captured. The application of Friedman's test and Mann–Whitney U tests with Bonferroni correction confirmed that the observed changes in pulmonary indices were statistically robust ($p < 0.001$). The greatest reduction was observed between baseline and the 12-week follow-up, underscoring the progressive nature of pollutant-induced respiratory decline.

Of particular concern was the observed decrease in the FEV_1/FVC ratio, which may signal the onset of obstructive airway alterations. These subclinical changes could predispose individuals to the later development of conditions such as asthma or COPD, especially if exposure continues unchecked.

This study emphasizes the underestimated vulnerability of young, otherwise healthy populations, who are often excluded from risk assessments. It highlights the invisible yet significant burden posed by urban air pollution, calling for urgent public health interventions. Strategies must include awareness generation, urban pollution control policies, and protective behavioral modifications, particularly targeted toward high-exposure groups such as commuting youth.

In conclusion, the results underscore an urgent need for continuous pulmonary surveillance, strengthened environmental regulations, and community-level action to protect at-risk populations from the escalating threat of ambient urban air pollution.

SUMMARY

SUMMARY

This study examined the impact of urban air pollution on lung function among healthy young adults aged 18 to 25 years in Ghaziabad, using fixed-site air quality monitoring data alongside standardized spirometric testing. A total of 75 participants underwent pulmonary function tests at three distinct time points: baseline, 24 hours, and 12 weeks.

The primary spirometric outcomes—Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV_1), and the FEV_1/FVC ratio—were chosen as sensitive markers of ventilatory function, airflow resistance, and overall pulmonary efficiency. Given the non-normal distribution of the data, non-parametric statistical approaches were adopted, including the Friedman test and Mann–Whitney U test with Bonferroni adjustment.

Initial pulmonary values across the cohort were within normal physiological ranges. However, progressive and statistically significant declines were documented over the 12-week period. Specifically, the mean FVC decreased from 4.08 L at baseline to 4.06 L after 24 hours, and further to 3.96 L by 12 weeks. Similarly, FEV_1 dropped from 3.27 L to 3.09 L, while the FEV_1/FVC ratio declined from 80.63% to 78.50% over the same interval.

These findings reveal an early yet sustained reduction in pulmonary function associated with continuous exposure to ambient urban pollutants. The results highlight the significant respiratory impact of urban air quality, even in populations typically regarded as low-risk.

CONCLUSION

CONCLUSION

This study clearly demonstrates that urban air pollution exerts a measurable and progressively detrimental effect on pulmonary function, even in young, healthy adults. Over the course of just 12 weeks, statistically significant reductions in key spirometric parameters—Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV_1), and the FEV_1/FVC ratio—were observed, suggesting the onset of early subclinical respiratory impairment.

These findings reinforce the urgent need for routine pulmonary surveillance, particularly in high-exposure urban zones, where young adults remain vulnerable despite lacking obvious risk factors. Immediate public health interventions are warranted, including: -

- Expansion of fixed-site air quality monitoring networks
- Dissemination of health advisories during pollution peaks
- Promotion of urban greening and emission-reduction strategies
- Implementation of targeted respiratory health education programs

Prioritizing such measures is essential to protect the lung health of youth populations and to curb the long-term burden of pollution-related respiratory diseases in India and globally.

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ANNEXURE

ANNEXURES

1. **PFT Consent Form**

2. **Tools For Data Collection**

PFT Consent form

Referral Date: _____

Booking Priority: ☐ ASAP ☐ Next available
☐ Book In _____

Referring Physician: _____
(please print)

Reason for Referral: _____

Existing Diagnosis: _____

Hgb Level (done within past 3 mos.): _____

Completed form to be faxed to NHH Lab **905-373-6912**

Patient Name: _____

Telephone #: _____

Health Card #: _____VC _____

DOB & Age: _____Height & Weight: _____

Address: _____

PATIENT HISTORY

Non-smoker	☐ Yes	☐ No
Former smoker	☐ Yes	☐ No
Pack Years _____		
Present smoker	☐ Yes	☐ No
Pack Years _____		

Does the patient have a history of:

Asthma	☐ Yes	☐ No
Emphysema	☐ Yes	☐ No
Bronchitis	☐ Yes	☐ No
Pneumonia	☐ Yes	☐ No
Restrictive Lung Disease	☐ Yes	☐ No
Interstitial Lung Disease/Fibrosis	☐ Yes	☐ No

Other pulmonary disorders _____

_____

Cardiac disease	☐ Yes	☐ No
(Possible) TB or other infectious diseases	☐ Yes	☐ No
Eye surgery in the past 6 weeks	☐ Yes	☐ No
Previous PFTs performed	☐ Yes	☐ No

When? _____

Where? _____

Recent chest x-ray	☐ Yes	☐ No
Recent ECHO	☐ Yes	☐ No
Recent cardiac stress test	☐ Yes	☐ No
Currently using Oxygen	☐ Yes	☐ No

MEDICATIONS

(bronchodilators/anti-inflammatories/oxygen **only***)*

_____

_____

_____

_____

TESTING REQUIRED

1. **Complete Pulmonary Function Study** ☐
   (flow-volume loop, pre & post bronchodilator, lung diffusion capacity, lung volumes, resting oximetry)
2. **Spirometry** ☐
3. **Pre/Post Bronchodilator Spirometry** ☐
4. **Lung Volumes & Airway Resistance** ☐
5. **Diffusion Capacity and Transfer Factor** ☐
6. **Arterial Blood Gases** ☐
   ☐On room air ☐On O_2 _____LPM
7. **Home Oxygen Assessment** ☐
   (includes resting and exertional oximetry with oxygen, if required, and/or arterial blood gases on room air)
   ☐For initial O_2 funding
   ☐For O_2 funding re-qualification
   Funding Renewal Date:_____
8. **6 Minute Walk Test** ☐
   ☐On room air ☐On O_2 _____LPM

_____

Physician Signature

_____

Fax Number

APPENDIX-2

Tools for data collection

1. Age (in years): ____
2. Gender: ☐ Male☐ Female☐ Other
3. Height (in cm): ____
4. Weight (in kg): ____
5. Residential Area: ____
6. Duration of residence in the current area (in years): ____
7. Have you been diagnosed with any respiratory condition

   (e.g. asthma, bronchitis)? ☐ Yes☐ No If yes,

   specify: _____
8. Do you experience any of the following symptoms? (Check all that apply): ☐ Cough

   ☐ Shortness of breath☐ Wheezing

   ☐ Chest tightness☐ Other: _____
9. Do you smoke? ☐ Never smoked☐ Former smoker☐ Current smoker.
10. Do you have a family history of respiratory diseases? ☐ Yes ☐ No If yes,

    specify_____

PROFORMA

(Details of patient to be included)

Patient Name: _____

Telephone No: _____

Health card: _____

DOB & Age: _____ Height & Weight: _____

Address: _____

Patient Name: ARCHIT ANSH

Telephone No: 8957254...

Health card: _____

DOB & Age: 02/04/2004 (21) Height & Weight: 177cm, 74kg

Address: Mohan Nagar

SANTOSH DEEMED TO BE UNIVERSITY (GHAZIABAD)

INFORMED CONSENT ENGLISH

INFORMED CONSENT FORM

Title of the thesis: Impact of Urban Pollution on Pulmonary Function in Young Adults Using Fixed Site Air Quality Data.

Name of the Investigator: Ms. Sadhvi

I have been explained to my full understanding in detail the nature and purpose of the above study, its potential risks/ benefits and the other details. I participate in the study voluntarily and I am free to withdraw from it at any time without giving any reason. I also understand that information collected from this study will be kept confidential.

Name of the participant:

Date :

Place :

Signature of the participant:

Name and signature of the person obtaining consent:

Date:

Witness name and signature

……

Address:

Date: Place:

_____

SANTOSH DEEMED TO BE UNIVERSITY (GHAZIABAD)

INFORMED CONSENT HINDI

सूचित सहमति पत्र

शोध प्रबंध का शीर्षक: स्थिर स्थल वायु गुणवत्ता डेटा का उपयोग करते हुए युवा वयस्कों में शहरी प्रदूषण का फुफ्फुसीय कार्य पर प्रभाव।

अन्वेषक का नाम: सुश्री साध्वी

मुझे उपरोक्त अध्ययन की प्रकृति और उद्देश्य, इसके संभावित जोखिम/लाभ और अन्य विवरणों के बारे में पूरी जानकारी दी गई है। मैं स्वेच्छा से इस अध्ययन में भाग ले रहा/रही हूँ और बिना कोई कारण बताए किसी भी समय इससे हटने के लिए स्वतंत्र हूँ। मैं यह भी समझता/समझती हूँ कि इस अध्ययन से एकत्रित जानकारी गोपनीय रखी जाएगी।

प्रतिभागी का नाम:

दिनांक:

स्थान:

प्रतिभागी के हस्ताक्षर:

सहमति प्राप्त करने वाले व्यक्ति का नाम और हस्ताक्षर:

दिनांक:

गवाह का नाम और हस्ताक्षर

.....

पता:

दिनांक: स्थान:

LETTER OF ETHICAL CLEARANCE FOR DISSERTATION FROM REGISTRAR OFFICE

SANTOSH
Deemed to be University

Celebrating 30 Impactful years

F. No. SU/2025/CRF/214 Dated: 25.05.2025

Subject: Approval of Research Project by the Institutional Human Ethics Committee.

Particular	Description
Project No.	EC/MSc Physiology/214
Project Title	Impact of Urban pollution on pulmonary function in young adults using fixed site air quality data
Student Name	Sadhvi
Guide	Dr Manisha Gupta
Department	M.Sc. Medical Physiology
Institution Name	Santosh Medical College & Hospital, Ghaziabad
Type of Study	Cross -sectional observational
Ethics Committee Decision	Approved

This Ethical clearance letter is valid for 2 years from the date of issue.

Jyoti Batra

Dr. Jyoti Batra
Member Secretary

Santosh Deemed to be University Dean Research

To,

Sadhvi,

Department of M.Sc. Medical Physiology

STATISTICIAN CERTIFICATE

SANTOSH Deemed to be University

SANTOSH Central Research Facility

CENTER FOR INTERDISCIPLINARY RESEARCH AND INNOVATION

To Whom It May Concern

This is to certify that the Post-Graduate Dissertation entitled **"Impact of Urban Pollution on Pulmonary Function in young adults using fixed site air quality data"** by **Ms. Sadhvi**, Department of Physiology M.Sc. (Medical Physiology) **(2022-25)** has been carefully assessed and authenticated by the Assistant Prof-Cum Bio-statistician of Santosh Deemed to be University.

This certification is issued based on the examination and review conducted by the Biostatistician, confirming adherence to statistical principles and practices.

Date: 30.07.2025

Signature:

Ms. Kirti Bharadwaj

(Assistant Professor cum Bio-Statistician)

Central Research Facility,

Santosh Deemed to be University

Ghaziabad, Delhi (NCR)

PLAGIRISM CERTIFICATE

sadhvi

IMPACT OF URBAN POLLUTION ON PULMONARY FUNCTION IN YOUNG ADULTS USING FIXED SITE AIR QUALITY DATA ms

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MASTER CHART

Code	Sex (M/F)	Age	Height	Weight	BMI	Baseline			After 24 hours			After 12 weeks		
						FVC	FEV_1	FEV_1/FVC	FVC	FEV_1	FEV_1/FVC	FVC	FEV_1	FEV_1/FVC
1	F	21	177	74	23.6	4.83	3.6	74.53	4.76	3.51	73.74	4.7	3.42	72.77
2	M	19	174	61	20.1	4.8	3.8	79.17	4.8	3.8	79.17	4.66	3.62	77.68
3	M	20	170	78	27	3.88	3.11	80.15	3.81	3.01	79.00	3.75	2.91	77.60
4	M	20	170	68	23.5	3.75	2.88	76.80	3.75	2.88	76.80	3.67	2.7	73.57
5	F	18	170	47	16.3	3.62	3.17	87.57	3.62	3.17	87.57	3.48	3.00	86.21
6	F	22	160	45	17.6	3.55	3.15	88.73	3.55	3.15	88.73	3.44	2.99	86.92
7	F	19	168	65	23	3.65	2.65	72.60	3.65	2.65	72.60	3.49	2.41	69.05
8	M	19	160	63	24.6	3.8	3.1	81.58	3.8	3.1	81.58	3.69	2.91	78.86
9	M	19	168	65	23	4.9	4.28	87.35	4.88	4.2	86.07	4.8	4.09	85.21
10	M	21	188	75	21.2	3.28	2.88	87.80	3.22	2.82	87.58	3.15	2.7	85.71
11	M	21	162	55	21	4.8	3.9	81.25	4.77	3.86	80.92	4.7	3.75	79.79
12	F	23	165	68	25	3.65	2.85	78.08	3.65	2.85	78.08	3.53	2.7	76.49
13	F	19	180	60	18.5	2.7	2.37	87.78	2.7	2.37	87.78	2.59	2.27	87.64
14	M	18	165	61	22.4	4.24	3.69	87.03	4.24	3.69	87.03	4.11	3.5	85.16
15	F	19	168	68	24.1	4.5	3.95	87.78	4.46	3.9	87.44	4.45	3.77	84.72
16	F	23	170	61	21.1	3.5	2.6	74.29	3.46	2.55	73.70	3.4	2.45	72.06
17	M	23	170	50	17.3	3.56	2.89	81.18	3.56	2.89	81.18	3.44	2.71	78.78
18	M	23	175	72	23.5	5.1	3.9	76.47	5.1	3.9	76.47	4.99	3.73	74.75
19	F	23	170	68	23.5	3.72	3.28	88.17	3.68	3.23	87.77	3.68	3.09	83.97
20	M	23	170	70	24.2	4.24	3.69	87.03	4.24	3.69	87.03	4.1	3.51	85.61
21	F	22	165	70	25.7	3.58	2.89	80.73	3.58	2.89	80.73	3.49	2.71	77.65
22	M	23	165	67	24.6	4.22	3.17	75.12	4.17	3.12	74.82	4.1	3.03	73.90
23	M	23	160	68	26.6	5.12	4.23	82.62	5.12	4.23	82.62	5.11	4.08	79.84
24	M	19	189	68	19	5.1	4.1	80.39	5.1	4.1	80.39	4.96	3.93	79.23
25	M	24	170	60	20.8	4.85	3.95	81.44	4.85	3.95	81.44	4.77	3.75	78.62
26	F	20	170	55	19	3.32	2.85	85.84	3.27	2.79	85.32	3.28	2.7	82.32
27	M	23	160	68	26.6	5.12	3.86	75.39	5.09	3.82	75.05	5.09	3.66	71.91
28	F	22	160	69	27	5.2	3.68	70.77	5.2	3.68	70.77	5.1	3.44	67.45
29	F	19	152	40	17.3	4.85	3.95	81.44	4.85	3.95	81.44	4.77	3.77	79.04
30	M	20	152	50	21.6	5.1	4.26	83.53	5.05	4.2	83.17	4.99	4	80.16
31	F	20	165	62	22.8	4.55	3.3	72.53	4.55	3.3	72.53	4.48	3.14	70.09
32	M	20	154	56	23.6	4.22	3.17	75.12	4.19	3.14	74.94	4.1	3.02	73.66
33	M	19	170	57	19.7	5.32	3.86	72.56	5.32	3.86	72.56	5.18	3.7	71.43
34	F	19	180	60	18.5	3.64	2.89	79.40	3.64	2.89	79.40	3.5	2.74	78.29
35	M	19	182	60	18.1	5.26	3.79	72.05	5.26	3.79	72.05	5.09	3.49	68.57
36	F	20	169	62	21.7	3.61	2.67	73.96	3.61	2.67	73.96	3.5	2.55	72.86
37	M	25	169	65	22.8	4.22	3.17	75.12	4.16	3.1	74.52	4.07	3	73.71
38	F	22	163	60	22.6	3.62	2.73	75.41	3.57	2.67	74.79	3.48	2.56	73.56
39	F	19	157	49	19.9	3.71	2.91	78.44	3.71	2.91	78.44	3.57	2.66	74.51
40	M	19	167	70	25.1	4.22	3.17	75.12	4.22	3.17	75.12	4.11	3.02	73.48
41	F	23	163	70	26.3	3.67	2.85	77.66	3.63	2.8	77.13	3.54	2.71	76.55
42	M	18	157	45	18.3	5.16	3.82	74.03	5.16	3.82	74.03	5.02	3.66	72.91
43	M	22	157	55	22.3	2.85	2.42	84.91	2.8	2.36	84.29	2.71	2.25	83.03
44	F	19	169	56	19.6	3.68	2.96	80.43	3.63	2.91	80.17	3.54	2.8	79.10
45	M	22	174	67	22.1	3.88	3.32	85.57	3.88	3.32	85.57	3.73	3.14	84.18
46	M	18	170	60	20.8	3.08	2.69	87.34	3.08	2.69	87.34	3	2.49	83.00
47	M	20	165	45	16.5	3.49	2.99	85.67	3.49	2.99	85.67	3.3	2.7	81.82
48	M	20	167	60	21.5	3.65	2.84	77.81	3.65	2.84	77.81	3.51	2.67	76.07
49	M	21	167	67	24	4.75	2.69	56.63	4.7	2.63	55.96	4.61	2.52	54.66
50	F	22	168	63	22.3	3.56	2.89	81.18	3.52	2.85	80.97	3.43	2.74	79.88
51	M	19	160	49	19.1	3.14	2.65	84.39	3.14	2.65	84.39	3.09	2.46	79.61
52	F	21	180	71	21.9	3.7	3.15	85.14	3.66	3.1	84.70	3.55	2.98	83.94
53	F	22	180	70	21.6	3.65	2.96	81.10	3.62	2.91	80.39	3.53	2.8	79.32
54	M	20	160	56	21.6	3.5	2.94	84.00	3.5	2.94	84.00	3.37	2.78	82.49
55	M	20	174	79	26.1	4.52	3.78	83.63	4.52	3.78	83.63	4.38	3.61	82.42
56	F	20	178	55	17.4	3.52	2.89	82.10	3.52	2.89	82.10	3.4	2.72	80.00
57	M	18	178	60	18.9	3.08	2.69	87.34	3.03	2.64	87.13	2.94	2.51	85.37
58	M	21	160	49	19.1	4.12	3.63	88.11	4.07	3.57	87.71	3.97	3.43	86.40
59	M	19	155	55	22.9	3.95	3.17	80.25	3.95	3.17	80.25	3.72	2.9	77.96
60	F	20	164	60	22.3	4.96	3.75	75.60	4.96	3.75	75.60	4.82	3.55	73.65
61	F	18	167	60	21.5	4.66	3.87	83.05	4.6	3.78	82.17	4.51	3.68	81.60
62	M	19	160	50	19.5	5.23	4.25	81.26	5.15	4.14	80.39	5.06	4.01	79.25
63	M	19	150	42	18.7	4.8	3.6	75.00	4.8	3.6	75.00	4.75	3.41	71.79
64	F	19	162	50	19.1	3.56	3.11	87.36	3.56	3.11	87.36	3.52	2.97	84.38
65	M	20	162	50	19.1	3.49	3	85.96	3.49	3	85.96	3.38	2.84	84.02
66	F	19	165	55	20.2	3.29	2.76	83.89	3.29	2.76	83.89	3.18	2.56	80.50
67	M	20	178	58	18.3	4.89	3.93	80.37	4.89	3.93	80.37	4.72	3.71	78.60
68	M	19	157	40	16.2	3.33	2.85	85.59	3.33	2.85	85.59	3.17	2.66	83.91
69	F	20	168	62	22	3.8	3.32	87.37	3.74	3.22	86.10	3.65	3.11	85.21
70	M	22	176	65	21	5.19	4.14	79.77	5.13	4.05	78.95	5.04	3.92	77.78
71	F	19	170	58	20.1	3.7	3.2	86.49	3.7	3.2	86.49	3.54	3	84.75
72	M	20	149	48	21.6	3.29	2.76	83.89	3.29	2.76	83.89	3.14	2.56	81.53
73	F	20	170	70	24.2	3.65	2.93	80.27	3.6	2.86	79.44	3.51	2.77	78.92
74	F	18	154	50	21.1	3.76	2.69	71.54	3.7	2.6	70.27	3.76	2.69	71.54
75	M	20	168	58	20.5	4.88	3.92	80.33	4.88	3.92	80.33	4.72	3.72	78.81